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PENSOFT

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Mountainous millipedes in Vietnam. IV. Three new *Anoplodesmus* Pocock, 1895 in northern Vietnam (Diplopoda, Polydesmida, Paradoxosomatidae), with notes on its phylogenetics

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Abstract

Three new *Anoplodesmus* species are described from northern Vietnam, namely *A. lobus* **sp. nov.**, *A. bilobus* **sp. nov.**, and *A. gladius* **sp. nov.** All three species belong to the A. *elongissimus* group, showing the relatively to extremely long gonopod solenophore. The phylogenetic relationships among *Anoplodesmus* species and other sulciferinin genera are also discussed.

Key Words

Biodiversity, phylogenetics, mountainous fauna, Southeast Asia, taxonomy

Introduction

Within the millipede family Paradoxosomatidae, *Anoplodesmus* is one of the most species-diverse genera, containing 40 species (see list below) distributed from northern India to Taiwan, through the Himalayas to the mainland of Malaysia, and Sumatra, Indonesia (Nguyen and Sierwald 2013; Sierwald et al. 2024).

Vietnam is known to harbor a rich fauna of millipedes. Furthermore, the country is located inside the distributional area of the genus *Anoplodesmus*. However, to date, only five species, *A. anichkini* Golovatch & Semenyuk, 2010, *A. borealis* Nguyen, 2010, *A. mirabilis* Golovatch, VandenSpiegel & Semenyuk, 2016, *A. nguyeni* Golovatch & Semenyuk, 2021, and *A. solenophorus* Nguyen, 2010, have been known from Vietnam. This paper is devoted to a better understanding of the millipede fauna through the descriptions of six new *Anoplodesmus* species from this country.

Materials and methods

Millipede specimens were collected from various parts of Vietnam during expeditions organized by Institute of Ecology and Biological Resources (IEBR, currently known as the Institute of Biology). Specimens were searched manually under the logs, rocks, and barks, collected by hand, and preserved in 80% ethanol.

Morphological characters were investigated with an Olympus SZX16 stereomicroscope. Gonopods were dissected for morphological examination and photographed. Colour images were taken at various focal planes using a Sony A6000 camera coupled with a SMZ800N Nikon stereomicroscope. UV images were taken using a Sony A6000 digital camera attached to the aforementioned SMZ800N Nikon stereomicroscope under the UV flashlight Nichia Convoy. Images were stacked using Helicon Focus version 7.0 and assembled in Adobe Photoshop CS6. Scanning electron microscope (SEM) images were

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taken using the system Prisma E (ThermoFisher Scientific) in the Institute of Ecology and Biological Resources.

Total DNA was extracted using Qiagen DNeasy Blood and Tissue Kits. A fragment of a mitochondrial gene (16S rRNA) was amplified using polymerase chain reaction (PCR). The primer sets for 16S follow Nguyen et al. (2017). PCR conditions for amplification of the 16S gene were an initial denaturation at 95 °C for 2 min followed by 36 cycles of 95 °C for 20 sec, 45 °C for 40 sec, and 72 °C for 1 min, and a final extension at 72 °C for 5 min. After thermal cycling, PCR products were checked for potentially successful amplification of a fragment of each gene using electrophoresis in 1% Agarose-TBE 1X. The successfully amplified PCR products were sent to the GenLab company (Vietnam) for purification and sequencing. The 16S sequences were verified using BLASTN 2.6.0+ (Zhang et al. 2000) and registered in GenBank with unique accession numbers. All verified sequences were aligned using multiple sequence alignment with the program ClustalX ver. 2 (Larkin et al. 2007). A maximum likelihood bootstrap analysis was conducted using the IQ-TREE server with 1,000 replicates at http://iqtree.cibiv.univie.ac.at/ (Trifinopoulos et al. 2016). The species *Antheromorpha festiva* (Brölemann, 1916) (tribe Orthomorphini) was selected as the root (Table 1).

All terminology follows Nguyen (2010) and Golovatch and Semenyuk (2021). Holotype and paratypes are deposited in the Institute of Ecology and Biological Resources (**IEBR**, currently known as the Institute of Biology), Hanoi, Vietnam.

Abbreviations: **IEBR-Myr** = Institute of Ecology and Biological Resources, Myriapod collection; **NHMUK** = Natural History Museum of the United Kingdom, London, England.

List of all known *Anoplodesmus* species (Nguyen and Sierwald 2013; Sierwald et al. 2024).

1. *Anoplodesmus affinis* (Golovatch, 1990) from Nepal.
2. *Anoplodesmus anichkini* Golovatch & Semenyuk, 2010 from southern Vietnam.
3. *Anoplodesmus anthracinus* Pocock, 1895 from Myanmar.
4. *Anoplodesmus aspinosus* Chen, Golovatch, Mikhajlova & Chang, 2010 from Taiwan.
5. *Anoplodesmus borealis* Nguyen, 2010 from northern Vietnam.
6. *Anoplodesmus chinensis* Golovatch, 1993 from China.
7. *Anoplodesmus cylindricus* (Carl, 1935) from India and Nepal.
8. *Anoplodesmus dyscheres* Attems, 1898 from Sumatra (Indonesia).
9. *Anoplodesmus elongissimus* (Golovatch, 1984b) from India.
10. *Anoplodesmus humberti* (Carl, 1902) from Sri Lanka.
11. *Anoplodesmus inornatus* (Humbert, 1865) from Sri Lanka.
12. *Anoplodesmus insignis* Attems, 1936 from India.
13. *Anoplodesmus layardi* (Humbert, 1865) from Sri Lanka.
14. *Anoplodesmus loebli* Golovatch, 2000 from Malaysia.
15. *Anoplodesmus luctuosus* (Peters, 1864) from Sri Lanka.
16. *Anoplodesmus magnus* Golovatch, 2015 from Nepal.
17. *Anoplodesmus malayanus* Golovatch, 1993 from Thailand.
18. *Anoplodesmus martensi* (Golovatch, 1990) from Nepal.
19. *Anoplodesmus mirabilis* Golovatch, VandenSpiegel & Semenyuk, 2016 from Highland of Vietnam.
20. *Anoplodesmus nguyeni* Golovatch & Semenyuk, 2021 from northcentral Vietnam.
21. *Anoplodesmus obesus* Pocock, 1895 from Myanmar.
22. *Anoplodesmus perplexus* (Golovatch, 1993) from Thailand.
23. *Anoplodesmus pinguis* Pocock, 1895 from Myanmar.
24. *Anoplodesmus rufocinctus* (Carl, 1932) from India.
25. *Anoplodesmus sabulosus* Attems, 1898 from India.
26. *Anoplodesmus saussurii* (Humbert, 1865) from Sri Lanka, Mascarene Islands (Mauritius), Fiji Islands.
27. *Anoplodesmus schawalleri* (Golovatch, 1990) from Nepal.
28. *Anoplodesmus similis* (Golovatch, 1990) from Nepal.
29. *Anoplodesmus simplex* (Humbert, 1865) from Sri Lanka.
30. *Anoplodesmus solenophorus* Nguyen, 2010 from southern Vietnam.
31. *Anoplodesmus spectabilis* (Karsch, 1881) from Java (Indonesia), listed as doubtful species by Nguyen & Sierwald (2013).
32. *Anoplodesmus spiniger* Chen, Golovatch, Mikhajlova & Chang, 2010 from Taiwan
33. *Anoplodesmus spinosus* Golovatch, 2016 from Nepal.
34. *Anoplodesmus splendidus* (Verhoeff, 1936) from India.
35. *Anoplodesmus striolatus* Pocock, 1895 from Myanmar.
36. *Anoplodesmus subcylindricus* (Carl, 1932) from India and Nepal.
37. *Anoplodesmus tanjoricus* (Pocock, 1892) from India.
38. *Anoplodesmus tarmani* Mršić, 1996 from Malaysia.
39. *Anoplodesmus thwaitesii* (Humbert, 1865) from Sri Lanka.
40. *Anoplodesmus ursula* (Attems, 1936) from India.

Taxonomic part

Order Polydesmida Pocock, 1897
Family Paradoxosomatidae Daday, 1889

Genus *Anoplodesmus* Pocock, 1895

Type species. *Anoplodesmus anthracinus* Pocock, 1895 (p. 798, fig. 5), by subsequent designation.

Type locality. Myanmar (Rangoon).

Type specimen. NHMUK.

Diagnosis. The genus is easily recognized by the following characters: paraterga modest or strongly reduced, legs usually with tarsal brushes, sterna usually with four cones, gonopod more or less elaborate, with or without a distofemoral process, both lamina medialis and lamina lateralis well-developed with several obvious lobes,

Table 1. Voucher species and accession numbers deposited in GenBank.

No.	Species	Locality	Voucher	Accession numbers	Source
1.	*Anoplodesmus mirabilis* Golovatch, VandenSpiegel & Semenyuk, 2016	Kon Ka Kinh National Park, Gia Lai Prov.	IEBR-Myr 635	PV441051	This study
2.	*Anoplodesmus solenophorus* Nguyen, 2010	Bu Gia Map National Park, Binh Phuoc Prov.	IEBR-Myr 74	PV441053	
3.	*Anoplodesmus nguyeni* Golovatch & Semenyuk, 2021	Pu Mat National Park, Nghe An Prov.	IEBR-Myr 156	PV441046	
4.	*Anoplodesmus lobus* **sp. nov.**	Ba Be National Park, Bac Can Prov.	IEBR-Myr 532	PV441049	
5.	*Anoplodesmus bilobus* **sp. nov.**		IEBR-Myr 236	PV441047	
6.	*Anoplodesmus bilobus* **sp. nov.**	Me Linh Biodiverisity Station, Vinh Phuc Prov.	IEBR-Myr 565	PV441050	
7.	*Anoplodesmus bilobus* **sp. nov.**	Tay Yen Tu Natural Reserve, Bac Giang Prov.	IEBR-Myr 510	PV441048	
8.	*Anoplodesmus bilobus* **sp. nov.**	Me Linh Biodiverisity Station, Vinh Phuc Prov.	IEBR-Myr SVE100	PV441055	
9.	*Anoplodesmus gladius* **sp. nov.**	Thuong Tien Nature Reserve, Hoa Binh Prov.	IEBR-Myr 641	PV441052	
10.	*Anoplodesmus gladius* **sp. nov.**	Pia Oac-Pia Den National Park, Cao Bang Prov.	IEBR-Myr 907	PV441054	
11.	*Anoplodesmus* sp.1	Cat Ba NP, Hai Phong Prov.	IEBR-209	KX755575	Nguyen (2017)
12.	*Anoplodesmus lobus* **sp. nov.**	Na Hang NR, Tuyen Quang Prov.	IEBR-479	KX755576	
13.	*Kronopolites accuminatus* (Attems, 1937)	Sapa, Lao Cai Prov.	IEBR-115	KX755578	
14.	*Kronopolites ramosus* Golovatch & Semenyuk, 2021	Pu Mat NP, Nghe An Prov.	IEBR-175	KX755579	
15.	*Kronopolites ramosus* Golovatch & Semenyuk, 2021	Pu Mat NP, Nghe An Prov.	IEBR-553	KX755580	
16.	*Oxidus gigas* (Attems, 1953)	Sapa, Lao Cai Prov.	IEBR-133	KX755581	
17.	*Oxidus gigas* (Attems, 1953)	Duc Xuan commune, Bac Quang Distr., Ha Giang Prov.	IEBR-516	KX755582	
18.	*Oxidus riukiuria* (Verhoeff 1940)	Okinawa Isls., Japan	IEBR-500	KX755583	
19.	*Sellanucheza grandis* (Golovatch, 1984a)	Pu Mat National Park, Nghe An Prov.	IEBR-177	KX755584	
20.	*Sellanucheza hoffmani* (Nguyen, 2011)	Phong Nha – Ke Bang National Park, Quang Binh Prov.	IEBR-182	KX755585	
21.	*Sellanucheza variata* (Attems, 1953)	Duc Xuan commune, Bac Quang Distr., Ha Giang Prov.	IEBR-516	KX755586	
22.	*Tylopus hilaroides* (Golovatch, 1984a)	Cuc Phuong NP, Ninh Binh Prov.	IEBR-198	KX755588	
23.	*Tylopus nodulipes* (Attems, 1937)	Phong Nha – Ke Bang NP, Quang Binh Prov.	IEBR-210	KX755589	
24.	*Tylopus roseiparaterga* (Nguyen, 2012)	Tam Dao NP, Vinh Phuc Prov.	IEBR-185A	KX755590	
25.	*Tylopus* sp.1	Cuc Phuong NP, Ninh Binh Prov.	IEBR-227	KX755591	
26.	*Tylopus* sp.2	Tay Yen Tu NR, Bac Giang Prov.	IEBR-509	KX755592	
27.	*Tylopus* sp.3	Pu Mat NP, Nghe An Prov.	IEBR-562	KX755593	
28.	*Tylopus* sp.4	Sapa, Lao Cai Prov.	IEBR-556	KX755594	
29.	*Tylopus* sp.5	Cuc Phuong NP, Ninh Binh Prov.	IEBR-228	KX755595	
30.	*Tylopus spinisterna* (Nguyen, 2012)	Bi Doup – Nui Ba NP, Lam Dong Prov.	IEBR-234	KX755596	
31.	*Antheromorpha festiva* (Brölemann, 1916)	Yon Don NP, Dak Lak Prov.	IEBR-519	KX755577	

solenomere as long as solonophore or extremely long (Golovatch and Semenyuk 2010).

The concept of this genus was discussed more clearly by Golovatch (1999) and Golovatch and Semenyuk (2010).

Remarks. This genus can be divided into two groups, based on the length of the solenomere. The *A. elongissimus* group, showing a relatively to extremely long solenomere, currently consists of seven species: *A. elongissimus*, *A. perplexus*, *A. spiniger*, *A. aspinosus*, *A. nguyeni*, *A. chinensis*, and *A. anichkini*. All of the remaining species seem to belong to the *A. anthracinus* group, characterized by a short solenomere, which either fails to or barely exceeds the solenophore (Golovatch and Semenyuk 2021).

Anoplodesmus lobus sp. nov.

https://zoobank.org/A2E1F141-1F7C-4CFE-9316-D43E3E363D89

Figs 1–5

Examined material. ***Holotype.*** Vietnam • male; Tuyen Quang Province, Na Hang Nature Reserve; 18 May 2011; Luong & An leg.; IEBR-Myr 478.

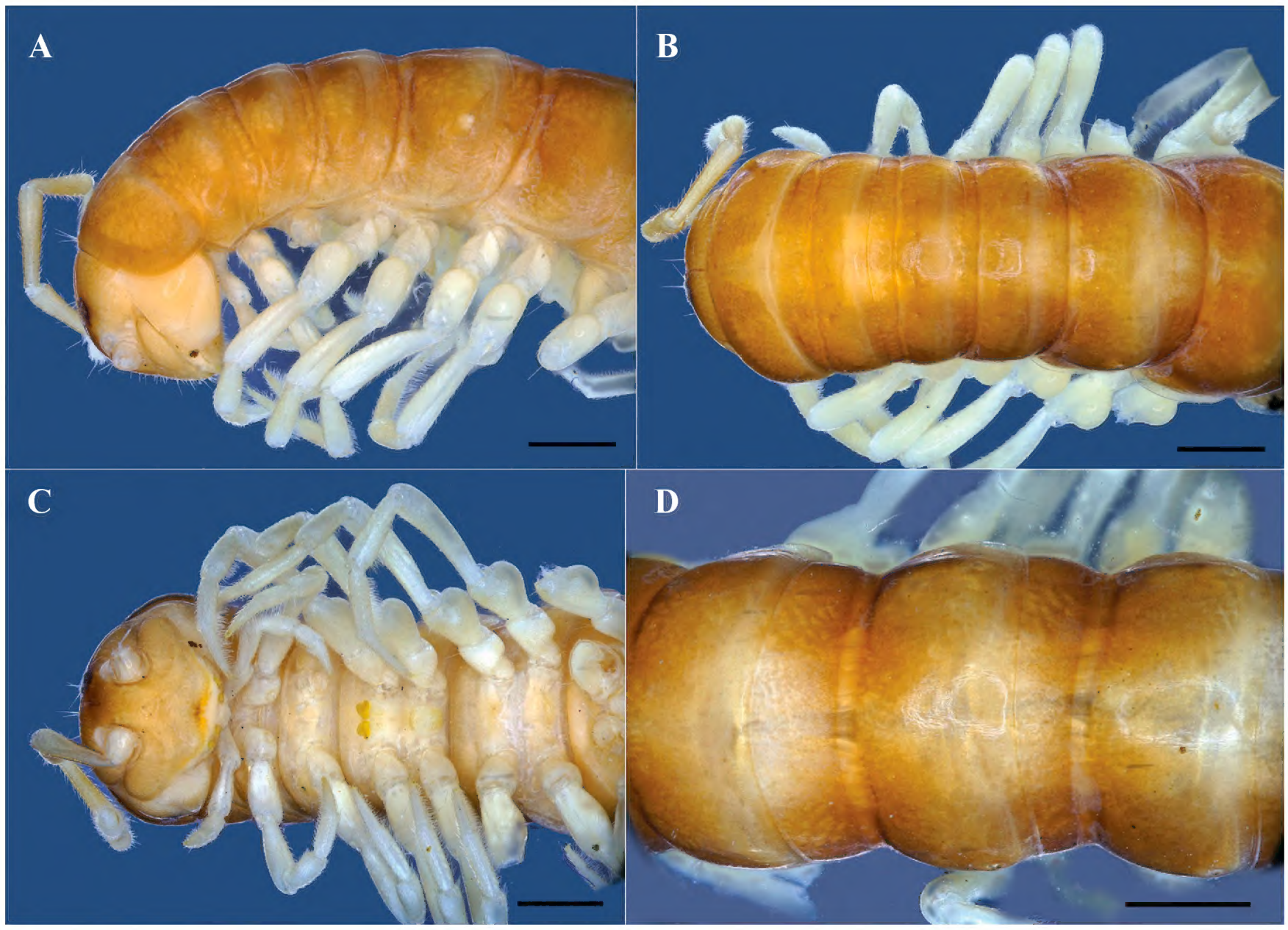

Figure 1. *Anoplodesmus lobus* sp. nov. Holotype (IEBR-Myr 478). **A–C.** Anterior part of the body, lateral view (**A**), dorsal view (**B**), ventral view (**C**); **D.** Body rings 8–10, dorsal view. Scale bars: 1 mm.

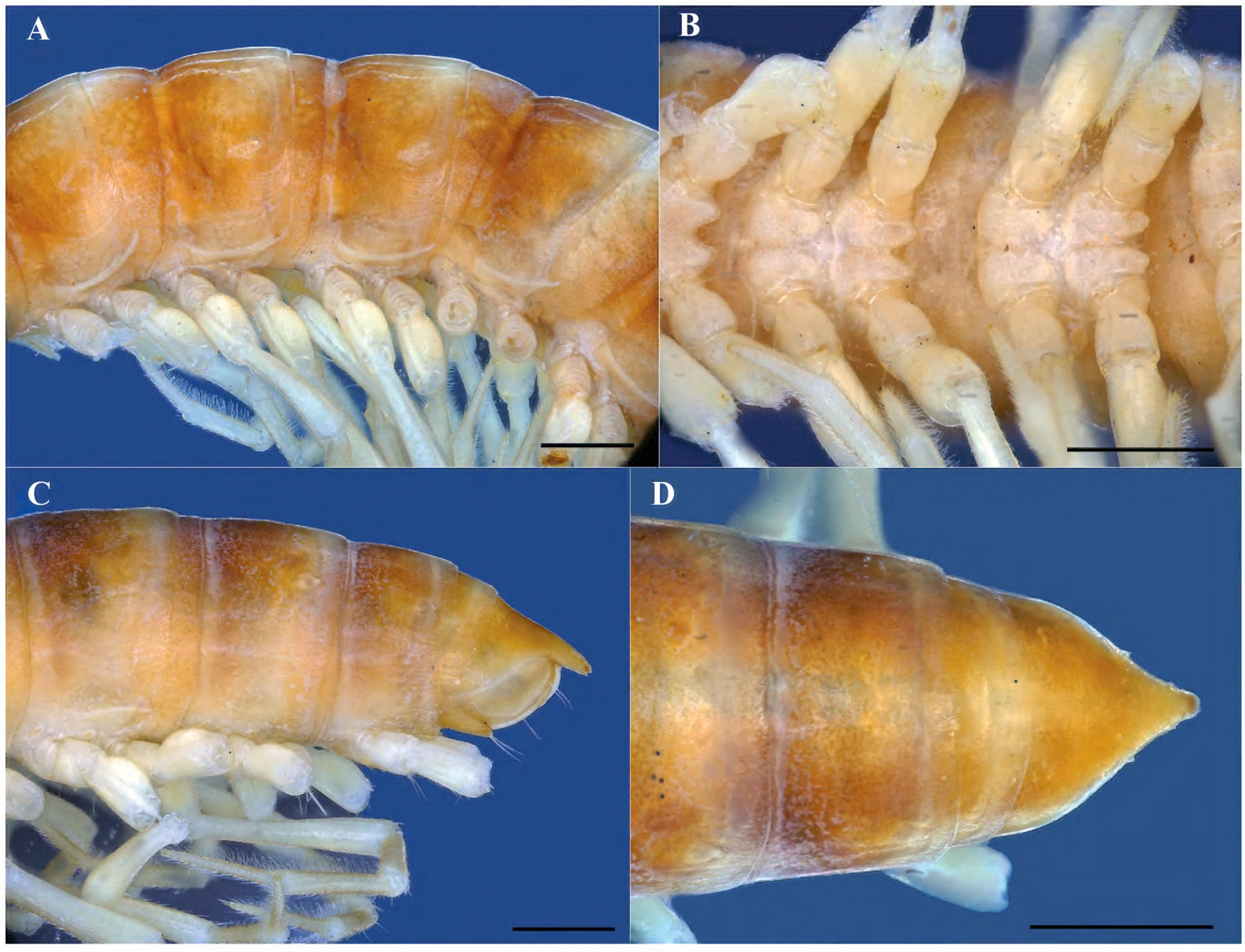

Figure 2. *Anoplodesmus lobus* sp. nov. Holotype (IEBR-Myr 478). **A.** Body rings 8–11, lateral view. **B.** Sternites 9–10, ventral view; **C**, **D.** Posterior part of the body, lateral view (**C**), dorsal view (**D**). Scale bars:1 mm.

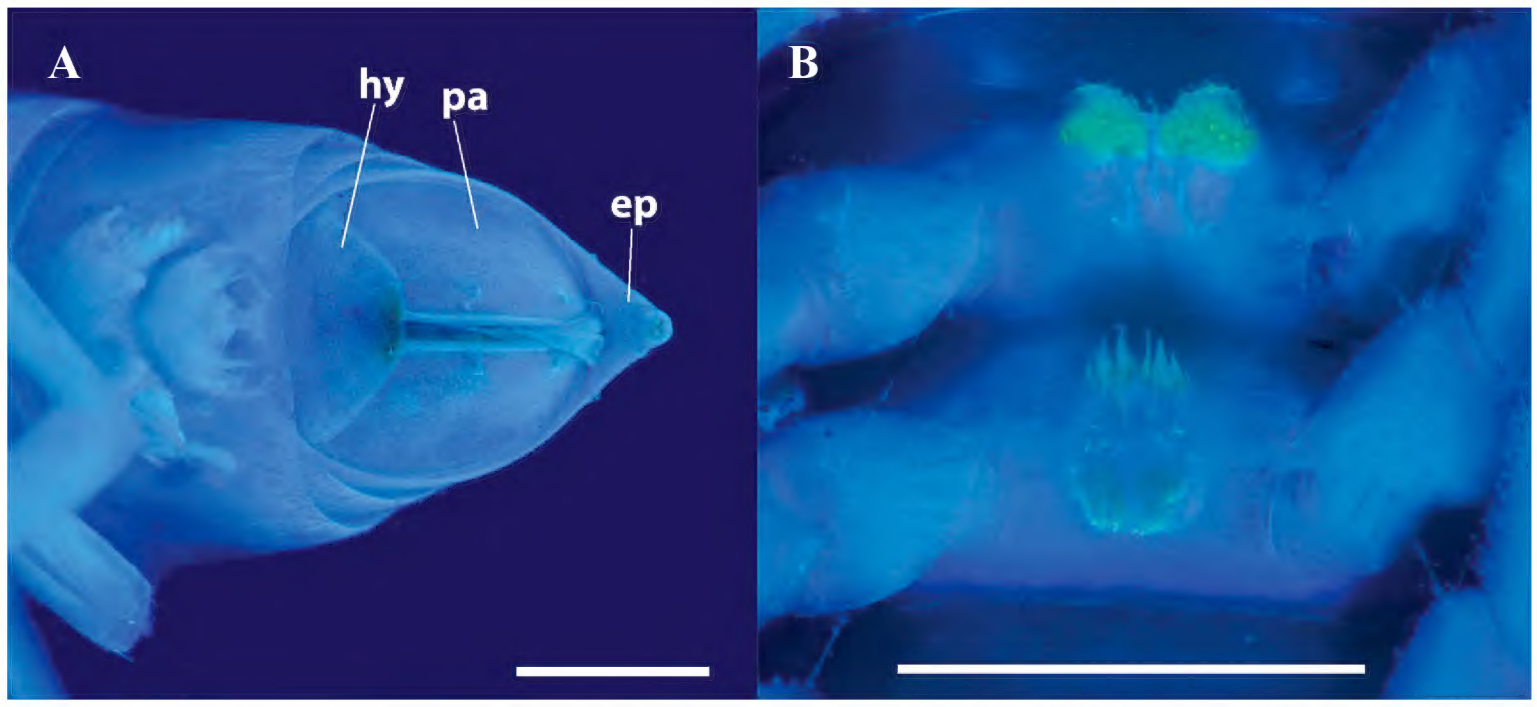

Figure 3. *Anoplodesmus lobus* sp. nov. Holotype (IEBR-Myr 478). **A.** Telson, ventral view; **B.** Sternum 5, ventral view. Abbreviations: hy = hypoproct; pa = paraproct; ep = epiproct. Scale bars: 1 mm.

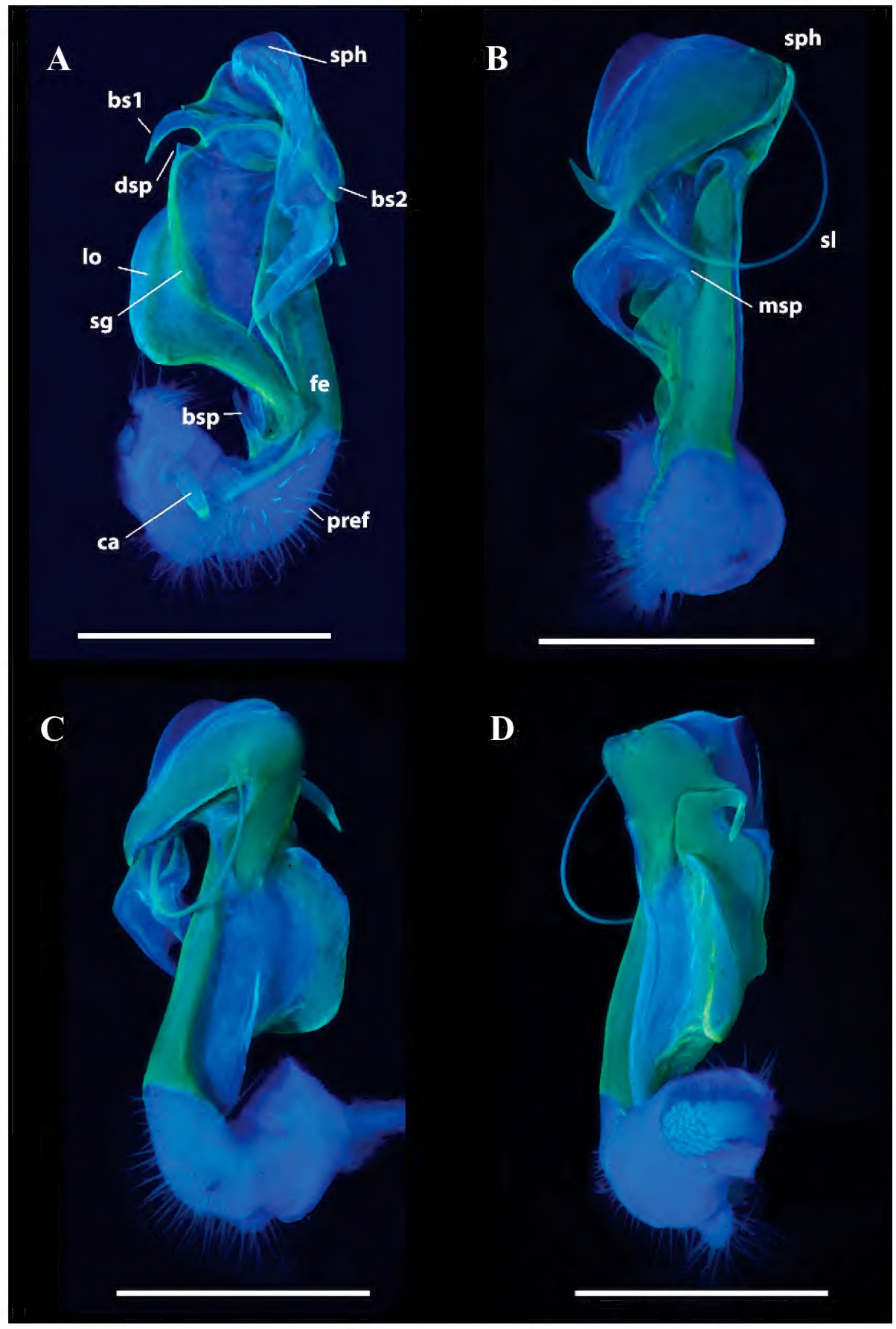

Figure 4. *Anoplode smus lobus* sp. nov. Holotype (IEBR-Myr 478). **A–D.** Left gonopod, dorsal view (**A**), lateral view (**B**), ventral view (**C**), mesal view (**D**). Abbreviations: ca = cannula; co = coxite; pref = prefemorite; fe = femorite; sg = seminal groove; sph = solenophore; sl = solenomere; bsp = basal spines of femorite; dsp = distal spine of femorite; bs1 = basal spine 1 of solenophore; bs2 = basal spine 2 of solenophore; lo = femoral lobe; msp = middle spine of solenophore. Scale bars: 1 mm.

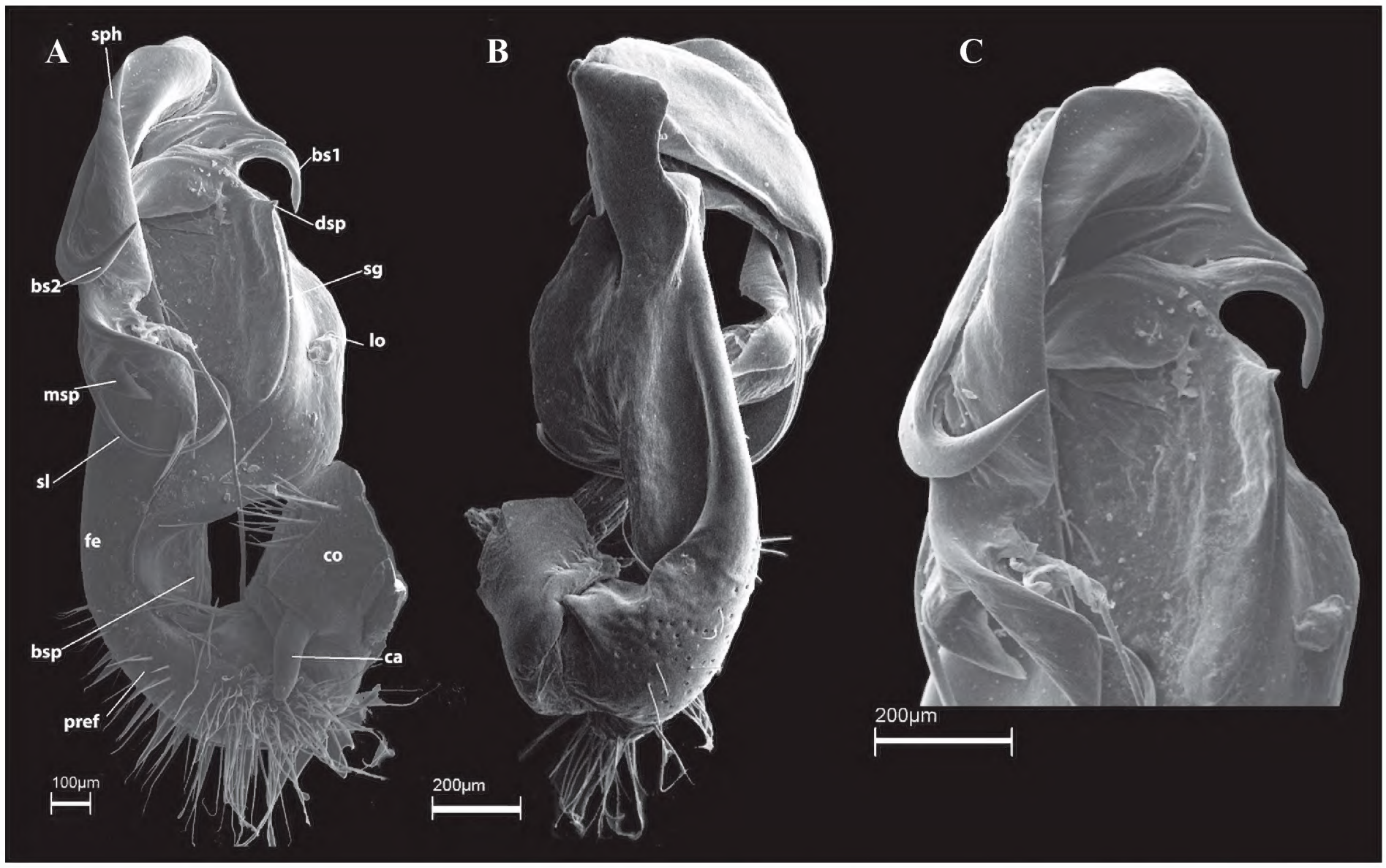

Figure 5. *Anoplodesmus lobus* sp. nov. Holotype (IEBR-Myr 479). SEM. **A, B.** Right gonopod, mesal view (**A**), lateral view (**B**); **C.** Distal part of right gonopod, mesal view. Abbreviations: ca = cannula; co = coxite; pref = prefemorite; fe = femorite; sg = seminal groove; sph = solenophore; sl = solenomere; bsp = basal spines of femorite; dsp = distal spine of femorite; bs1 = basal spine 1 of solenophore; bs2 = basal spine 2 of solenophore; lo = femoral lobe; msp = middle spine of solenophore.

Paratypes. VIETNAM • 1 male, 8 females; Tuyen Quang Province, Na Hang Nature Reserve, Nam Trang Cave, entrance, 22.33423°N, 105.42817°E; 449 m a.s.l.; 18 May 2011; Luong & An leg.; IEBR-Myr 479 • 7 males, 5 females; Bac Can province, Ba Be National Park; 22.25083°N, 105.81499°E, 400–500 m a.s.l., 10-11 July 2013; limestone forest; Anh D. Nguyen leg.; IEBRMyr 532.

Etymology. The species epithet "*lobus*" adjective, is used to emphasize the large lobe on gonopod femorite.

Diagnosis. The species is characterized by having submoniliform body, poorly developed paraterga, gonopod femorite enlarged distad, with a large membraneous lobe and a distal spiniform process on dorsal side; solenophore complex curved down, with two basal spines and a distal laminate lobe; tip strongly bifid; solenomere relatively long.

Description. ***Size*:** body length 31.34–32.11 mm (males), 31.29–32.78 mm (females). Width of midbody pro- and metazona 2.13–2.18 mm (males), 2.88–3.21 mm (females), and 2.45–2.56 mm (males), 3.2–3.47 mm (females), respectively. Length of holotype 31.34 mm, width of pro- and metazona 2.18 and 2.56 mm, respectively.

Coloration generally dark brown, except for yellowish brown middle parts of metaterga, as well as pleura and sterna. Legs pale yellow, antennae light brown.

***Head*:** labrum and frons densely setose, vertex sparsely setose along epicranial suture. Latter deep, distinct, running from rear margin of vertex down to labrum. Antennae slender and very long, reaching to segment 4 if stretched laterally. Antennomere 1=7<6<3=4=5<2 in length.

Collum (Fig. 1A, B): a little wider than head, surface smooth, with two rows of setae: 4+4 close to anterior margin and 2+2 nearly posterior margin.

Body (Figs 1B, D, 2A, C) submoniliform, width of body ring 3<4<2=5, parallel-sided on body rings 5–16, thereafter gradually tapering towards telson. Metatergal surface smooth, shagreened, shining, with only one row of 2+2 setae near anterior margin (broken in preserved specimens). Transverse sulcus poorly developed, superficial on metaterga 5–18. Prozona and pleura also shagreened and shining. Stricture dividing pro- and metazona rather distinct and smooth, neither striolate nor beaded (Figs 1, 2).

Paraterga (Figs 1A, B, D, 2A, C, D) strongly reduced, almost missing, slightly more easily traceable as lateral keels on pore-bearing body rings than on poreless ones. Ozopore formula normal, pores located on paraterga 5, 7, 9, 10, 12, 13, and 15–19. Pleurosternal carinae well-developed until body ring 16, missing on subsequent ones (Figs 1A, 2A, C).

Telson (Figs 2C, D, 3A): Epiproct long and curved down, with four small spinnerets at tip. Hypoproct subtrapeziform, with two distolateral setiferous knobs (Fig. 3A).

Sternites (Figs 1C, 2B) sparsely setose, cross-impression with both transverse and longitudinal sulci moderately developed. Sternal cones obvious, front pairs slightly stouter, caudal pairs somewhat slenderer and longer (Fig. 2B). Sternite 5 with an elevated bifid lamina between coxae 4 and a ventrad-elevated setiferous process between coxae 5 (Figs 1C, 3B).

Legs slender and long, about 1.7 times as long as body height. Tarsal brushes present until ring 17, thereafter missing. Prefemora swollen dorsally. Femora without modifications.

Gonopod (Figs 4, 5) rather complex. Coxite (co) stout, about half length of telopodite, distoventral part sparsely setose. Prefemoral part (pref) as usual densely setose. Femorite (fe) stout, enlarged distad, with a basal straight spine (bsp), a large membraneous lobe (lo), and a small distal spiniform process (dsp) on dorsal side, separated from postfemoral region laterally by a distinct demarcation sulcus. Solenophore very complex, curved down, with two basal spines (bs1 and bs2) and a spiniform process (sp) in middle; tip strongly bifid. Seminal groove (sg) running distodorsad fully on mesal side of femorite. Solenomere (sl) flagelliform, relatively long, only its proximal half sheathed by solenophore.

Remarks. The new species belongs to the *A. elongissimus* group with a relatively to extremely long solenomere. It clearly differs from its five congeners, *A. elongissimus*, *A. perplexus*, *A. spiniger*, *A. aspinosus*, and *A. anichkini*, in gonopod conformation, especially the solenophore structure.

Habitats. The species was found under the leaf litter in moist environments. It moves quickly when disturbed.

Anoplodesmus bilobus sp. nov.

https://zoobank.org/A423D64A-7008-4ECA-A7F9-9D9B53713364

Figs 6–10

Examined material. ***Holotype.*** Vietnam • male; Bac Giang Province, Son Dong District, Tay Yen Tu Natural Reserve, Khe Ro; forest; 17–18 May 2013; Phung Thi Hong Luong leg.; IEBR-Myr 510H.

Paratypes. Vietnam • 3 males, 4 females; same data as for the holotype; IEBR-Myr 510P • 2 males; Vinh Phuc Province, Phuc Yen town, Me Linh station for biodiversity; forest; 9–16 September 2016; Anh D. Nguyen leg.; IEBR-Myr 565.

Etymology. The species epithet "*bilobus*" adjective, is used to emphasize the solenophore being strongly divided into two large lobes.

Diagnosis. The species is characterized by having sub-moniliform body, poorly developed paraterga, gonopod femorites stout, somewhat waisted at the middle, basal part swollen dorsally, and separated from postfemoral

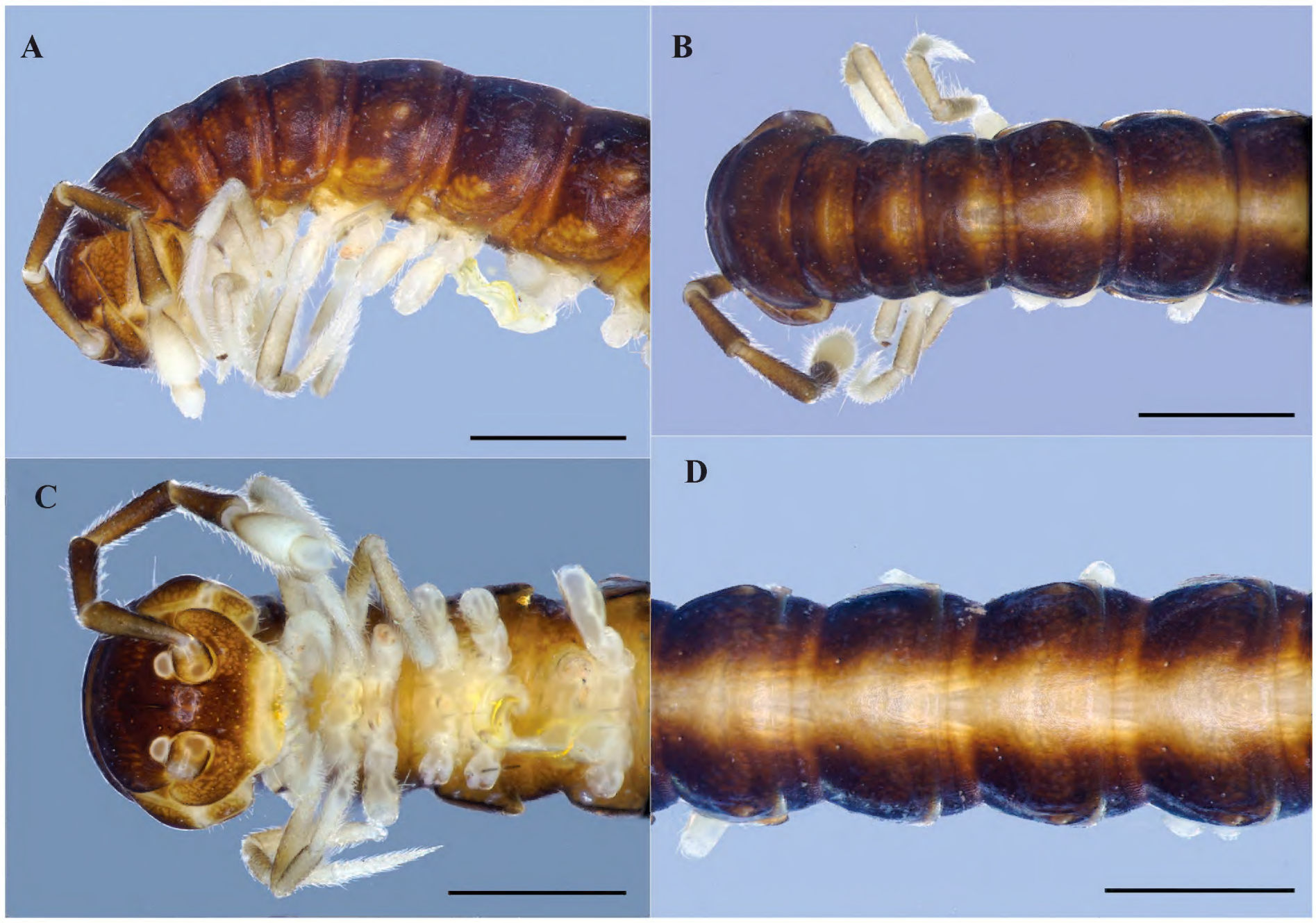

Figure 6. *Anoplodesmus bilobus* sp. nov. Holotype (IEBR-Myr 510H). **A–C.** Anterior part of the body, lateral view (**A**), dorsal view (**B**), ventral view (**C**); **D.** Body rings 7–10, dorsal view. Scale bars: 1 mm.

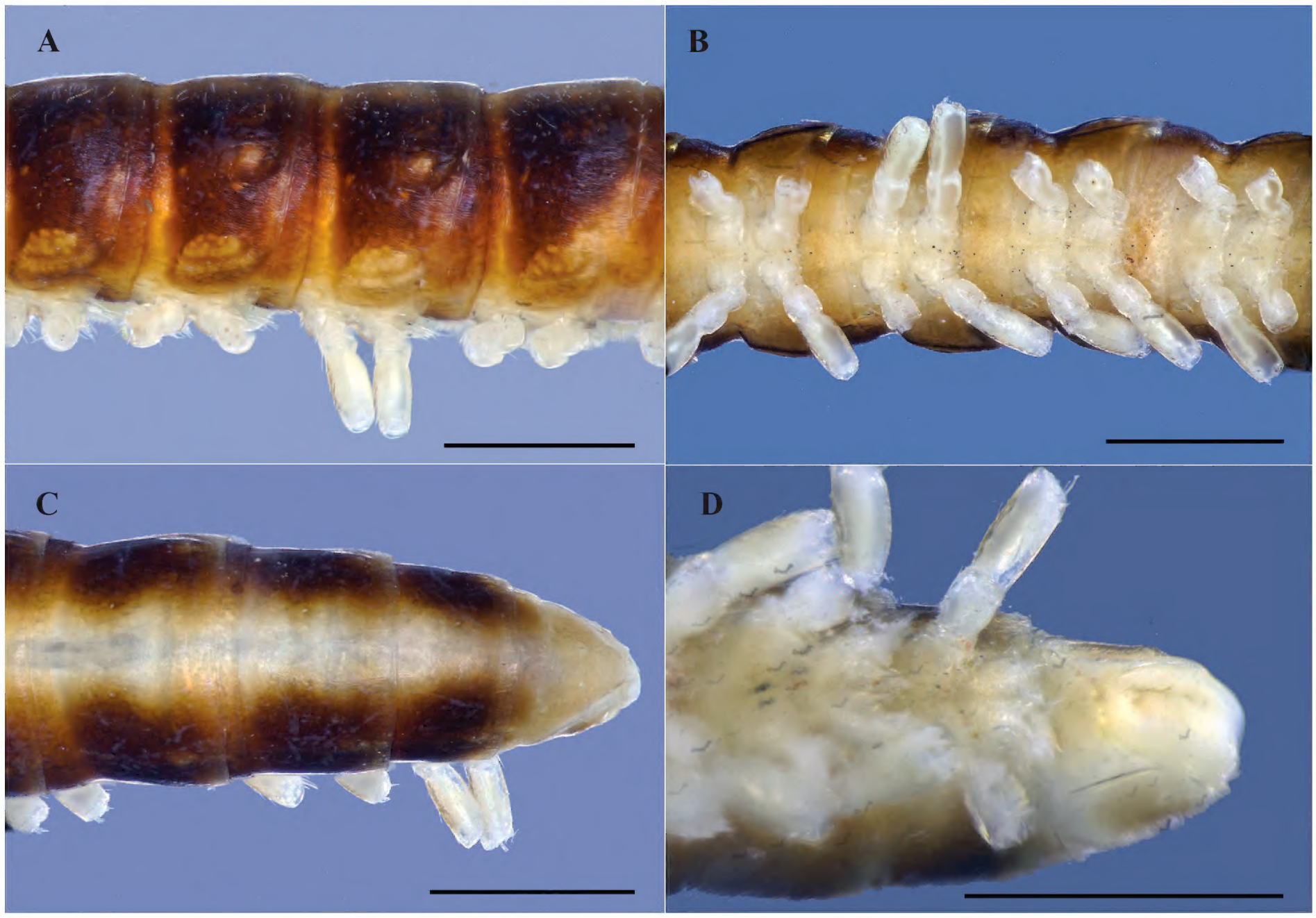

Figure 7. *Anoplodesmus bilobus* sp. nov. Holotype (IEBR-Myr 510H). **A.** Body rings 8–10, lateral view; **B.** Sternites 8–11, ventral view; **C.** Posterior part of body, dorsal view; **D.** Paraprocts and hypoproct, ventral view. Scale bars: 1 mm.

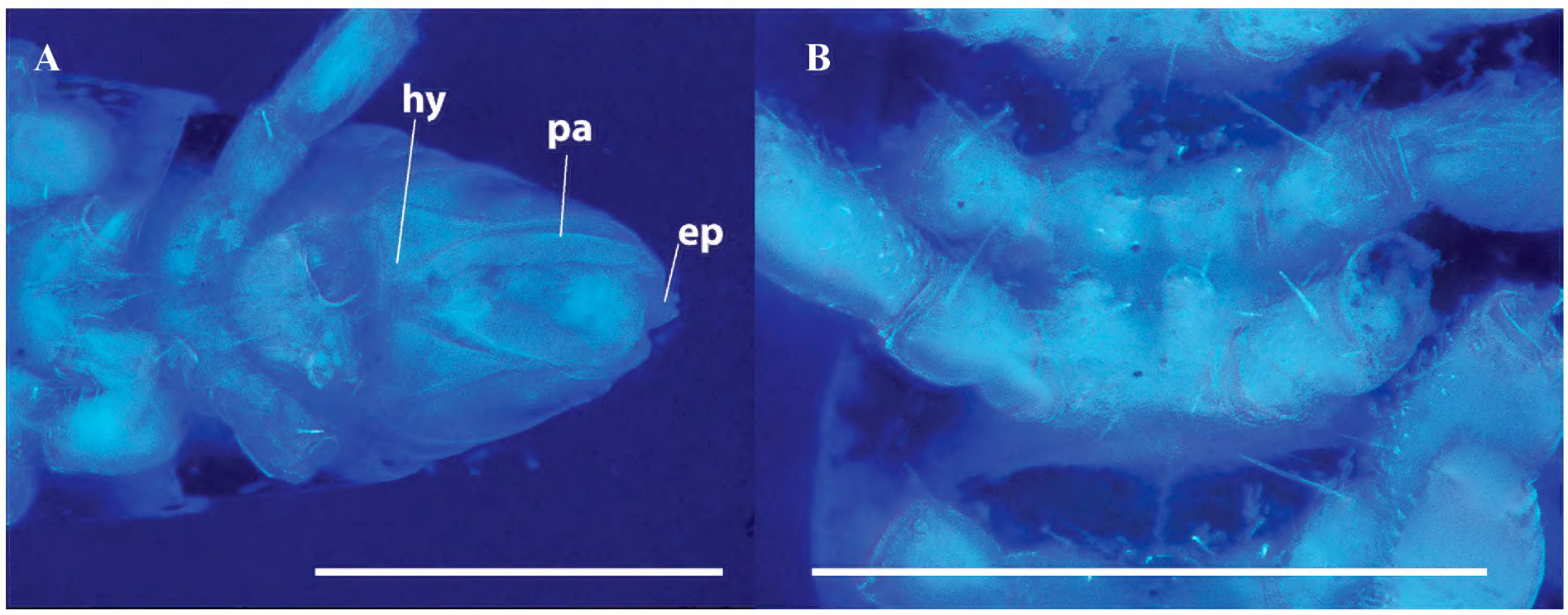

Figure 8. *Anoplodesmus bilobus* sp. nov. Holotype (IEBR-Myr 510H). **A.** Telson, ventral view; **B.** Sternum 5, ventral view. Abbreviations: hy = hypoproct; pa = paraproct; ep = epiproct. Scale bars: 1 mm.

region laterally by a distinct demarcation sulcus; solenophore rather simple, with only a long basal process, coiled posteriad; solenomere relatively long.

Description. ***Size*:** body length 13.5–15.0 mm (males), 17.66–18.85 mm (females). Width of midbody pro- and metazona 1.04–1.19 mm (males), 1.51–1.68 mm (females), and 1.20–1.27 mm (males), 1.57–1.76 mm (females), respectively. Length of holotype 14.44 mm, width of pro- and metazona 1.10 and 1.24 mm, respectively.

***Coloration*:** generally reddish brown, except for a brownish yellow broad, longitudinal band in middle metaterga, as well as lower part of pleura and sterna. Legs pale yellow, antennae light brown, except antennomeres 6 and 7 whitish.

Head (Fig. 6C): labrum and frons densely setose, vertex sparsely setose along epicranial suture. Latter deep, distinct, running from rear margin of vertex down to labrum. ***Antennae*** slender and very long, reaching

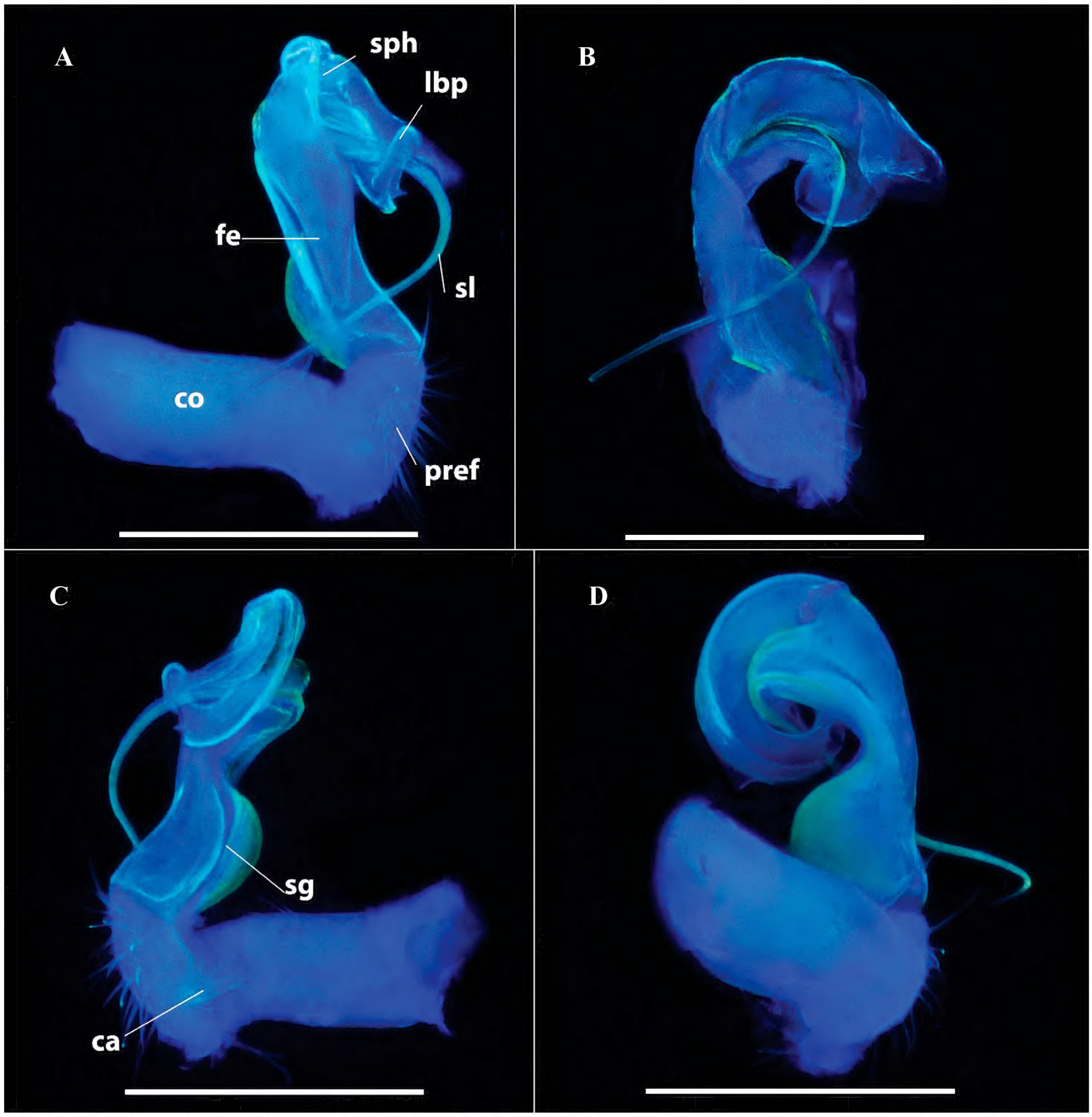

Figure 9. *Anoplodesmus bilobus* sp. nov. Holotype. (IEBR-Myr 510H). **A–C.** Right gonopod, lateral view (**A**), ventral view (**B**), mesal view (**C**). Abbreviations: ca = cannula; co = coxite; pref = prefemorite; fe = femorite; sg = seminal groove; sph = solenophore; sl = solenomere; lbp = long basal process of solenophore. Scale bars: 1 mm.

behind segment 5 if stretched laterally; antennomere 1=7<6<5<2=4 in length.

Collum (Fig. 6B): a little smaller than head, surface smooth, with two rows of setae: 4+4 close to anterior margin and 2+2 nearly posterior margin. All setae broken.

Body (Figs 6A, B, 6D, 7A–C) submoniliform, width of ring 3<4<2=5, parallel-sided on rings 5–16, thereafter gradually tapering towards telson. Metatergal surface smooth, shagreened, shining, with only one row of 2+2 setae near anterior margin. Transverse sulcus very poorly developed, superficial. Prozona and pleura also shagreened and shining. Stricture dividing pro- and metazona rather distinct and smooth, neither striolate nor beaded.

Paraterga (Figs 6A, B, 6D, 7A–C) strongly reduced, almost missing, slightly more easily traceable as lateral keels on pore-bearing rings than on poreless ones. Ozopore formula normal, pores located on paraterga 5, 7, 9, 10, 12, 13, and 15–19. Pleurosternal carinae well-developed until segment 16, missing on subsequent ones (Figs 6A, 7A).

Telson (Figs 7D, 8A): Epiproct long and curved down, with four small spinnerets at tip. Paraprocts semi-circular, each with two setae located on disk. Hypoproct roundly triangular, with two distolateral setiferous knobs (Figs 7D, 8A).

Sternites (Figs 7B, 8B) sparsely setose, cross-impression with both transverse and longitudinal sulci moderately

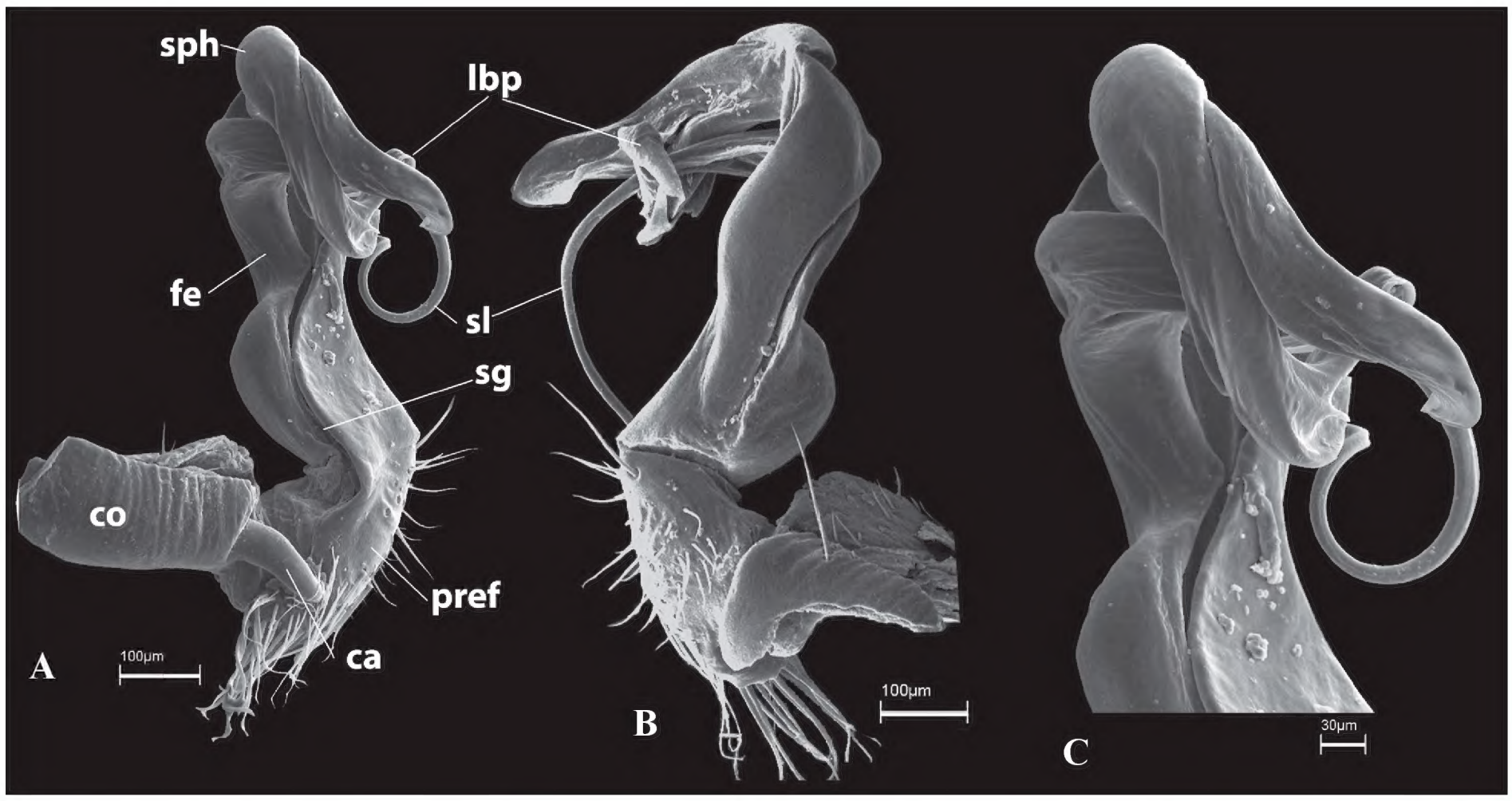

Figure 10. *Anoplodesmus bilobus* sp. nov. Holotype. (IEBR-Myr 510H). SEM. **A, B.** Left gonopod, mesal view (**A**), lateral view (**B**); **C.** Distal part of left gonopod, mesal view. Abbreviations: ca = cannula; co = coxite; pref = prefemorite; fe = femorite; sg = seminal groove; sph = solenophore; sl = solenomere; lbp = long basal process of solenophore.

developed. Sternal cones small but obvious, front pairs even smaller than caudal pairs (Fig. 7B). Sternite 5 with two independent small setiferous rectangular laminae between coxae 4 and two similar laminae between coxae 5 (Fig. 8B).

Legs slender and about 1.6 times as long as body height. Tarsal brushes present until ring 16, thereafter missing. Prefemora swollen dorsally. Femora without modifications.

Gonopod (Figs 9, 10) rather complex. Coxite (co) cylindrical, about half length of telopodite, distoventral part sparsely setose. Prefemoral part as usual densely setose. Femorite (fe) stout, somewhat waisted at the middle, basal part swollen dorsally, and separated from postfemoral region laterally by a distinct demarcation sulcus. Solenophore (sph) rather simple, with only a long, posteriad-coiled basal process (lbp). Seminal groove (sg) running distodorsad fully on mesal side of femorite, Solenomere (sl) flagelliform, relatively long, only its proximal half sheathed by solenophore.

Remarks. The new species obviously belongs to the *A. elongissimus* group with a relatively to extremely long solenomere. It clearly differs from its congeners in having a simple gonopod solenophore.

Habitats. The species was found under the leaf litter in moist environments. It moves quickly when disturbed.

Anoplodesmus gladius sp. nov.

https://zoobank.org/E489D8AC-F7B2-4695-9FA7-5BCA6DAC563B

Figs 11–15

Examined material. ***Holotype.*** Vietnam • male; Cao Bang Province, Pia Oac-Pia Den National Park; 22.5943°N, 105.8846°E; 1,200 m a.s.l.; bushes; 9 May 2021; Anh D. Nguyen leg.; IEBR-Myr 903H.

Paratypes. Vietnam • 1 male; same data as for the holotype; IEBR-Myr 903P • 2 males; Cao Bang Province, Ha Lang District, Duc Quang commune, outside Pia Ma cave; 10 October 2023; Anh D. Nguyen leg.; IEBR-Myr 894 • 1 male, 1 female; same locality, but on the way to Hang Ong; 22.5540°N, 105.8622°E; 850 m a.s.l.; 8 May 2021; Anh D. Nguyen leg.; IEBRMyr 907 • 3 males, 3 females; Hoa Binh Province, Kim Boi District, Thuong Tien Nature Reserve; 20.64039°N, 105.44606°E; 12 May 2017; Hung D. Nguyen leg.; IEBR-Myr 641.

Etymology. The species epithet "*gladius*" adjective, is used to emphasize the blade-shaped solenophore of the male gonopod.

Diagnosis. The species is characterized by having sub-moniliform body, poorly developed paraterga, gonopod femorite stout, enlarged distad, swollen dorsally. distal part with an acute spine distomesally; curved posteriad, large blade-shaped with an acute terminal, basal part with a rectangular process; solenomere short but longer than solenophore.

Description. ***Size*:** body length 25.97–28.02 mm (males), 33.33 mm (female). Width of midbody pro- and metazona 2.15–2.36 mm (males), 3.08 mm (female), and 2.30–2.48 mm (males), 3.24 mm (female), respectively. Length of holotype 25.97 mm, width of pro- and metazona 2.15 mm and 2.30 mm, respectively.

***Coloration*:** generally brownish yellow, except prozona and anterior halves of metatzona brownish. Legs pale yellow, antennae light brown.

Head (Fig. 11C): labrum and frons densely setose, vertex sparsely setose along epicranial suture. Latter deep, distinct, running from rear margin of vertex down to labrum. Antennae slender and very long, reaching behind segment 6 if stretched laterally; antennomere 1=7<6<5<2=4 in length.

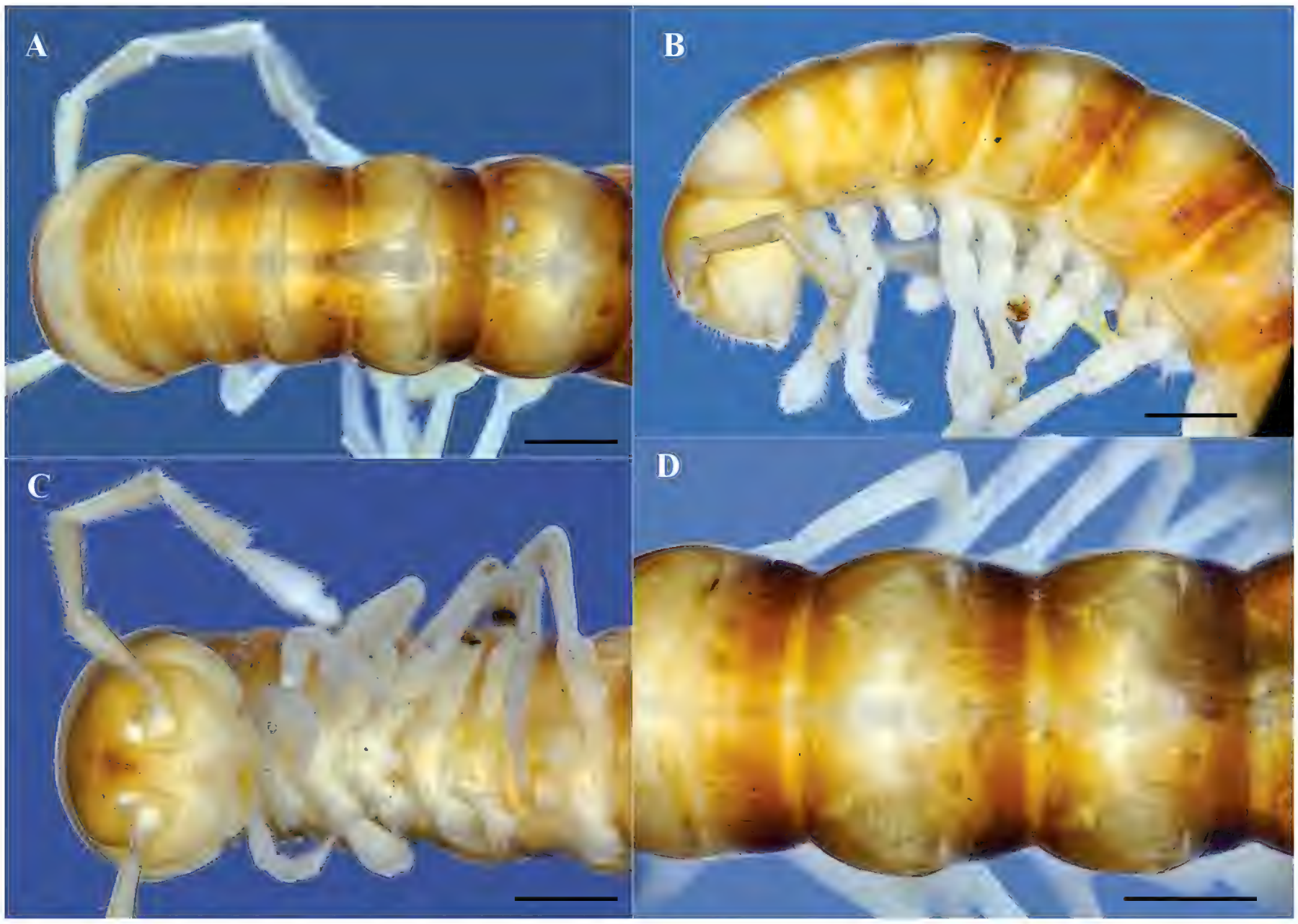

Figure 11. *Anoplodesmus gladius* sp. nov. Holotype (IEBR-Myr 903H). **A–C.** Anterior part of body, dorsal view (**A**), lateral view (**B**), ventral view (**C**); **D.** Body rings 8–10, dorsal view. Scale bars: 1 mm.

Figure 12. *Anoplodesmus gladius* sp. nov. Holotype (IEBR-Myr 903H). **A.** Body rings 7–10, lateral view; **B.** Sternites 8–10, ventral view; **C.** Telson and epiproct, dorsal view; **D.** Paraprocts and hypoproct, subventral view. Scale bars: 1 mm.

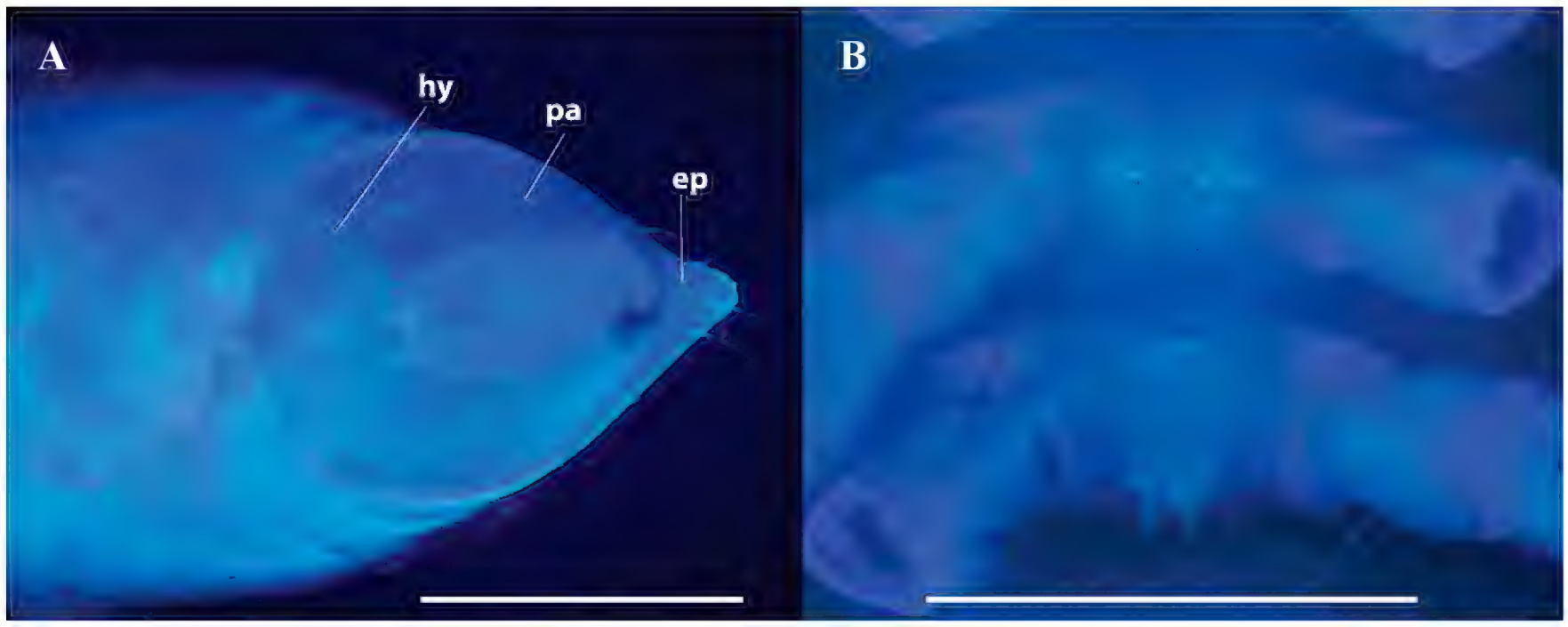

Figure 13. *Anoplodesmus gladius* sp. nov. Holotype (IEBR-Myr 903H). **A.** Telson, ventral view; **B.** Sternum 5, ventral view. Abbreviations: hy = hypoproct; pa = paraproct; ep = epiproct. Scale bars: 1 mm.

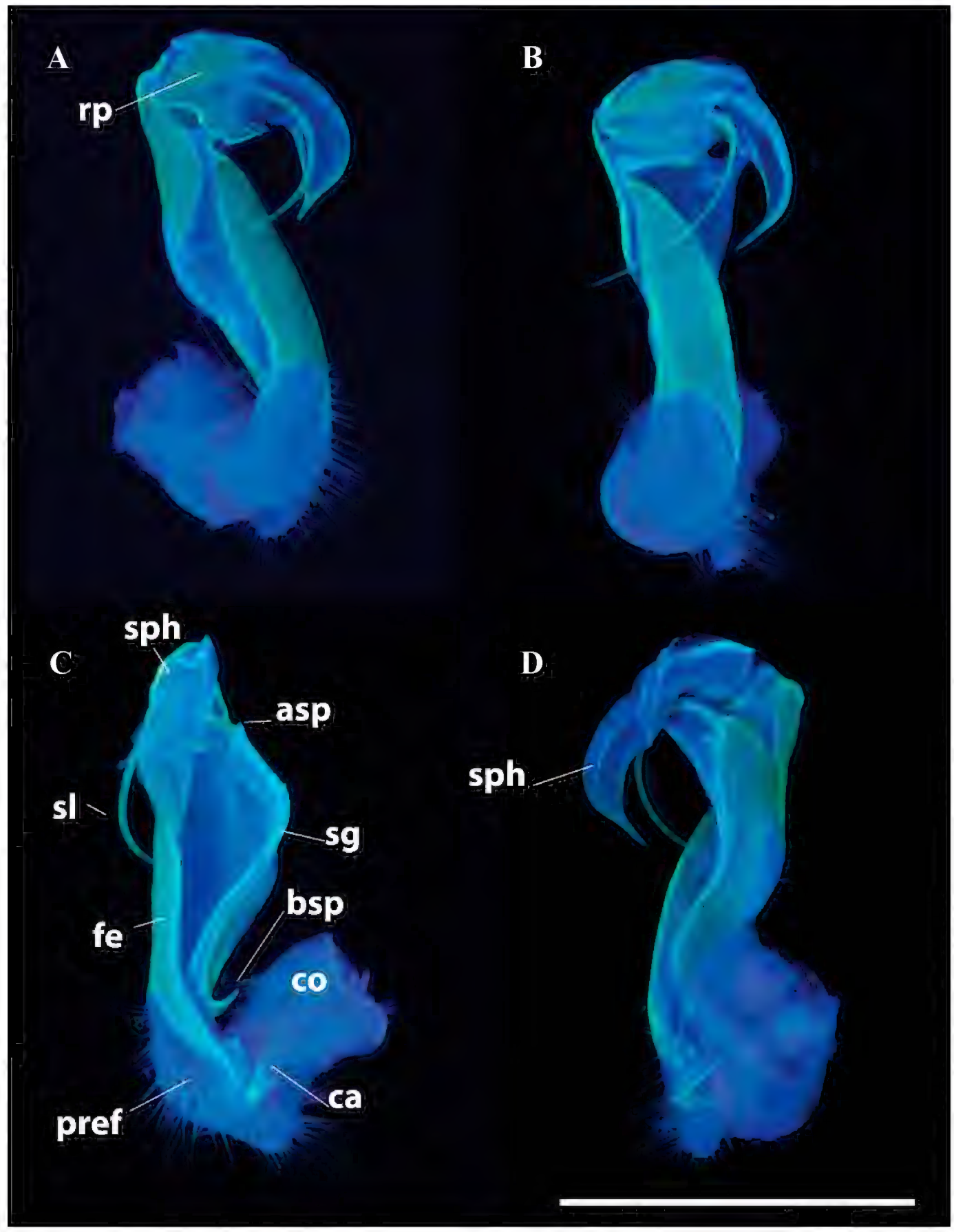

Figure 14. *Anoplodesmus gladius* sp. nov. Holotype (IEBR-Myr 903H**). A–D.** Left gonopod, sublateral view (**A**), ventral view (**B**), mesal view (**C**), subdorsal view (**D**). Abbreviations: ca = cannula; co = coxite; pref = prefemorite; fe = femorite; sg = seminal groove; sph = solenophore; sl = solenomere; bsp = basal spine of femorite; asp = apical spine of femorite; rp = rectangular process of solenophore. Scale bars: 1 mm.

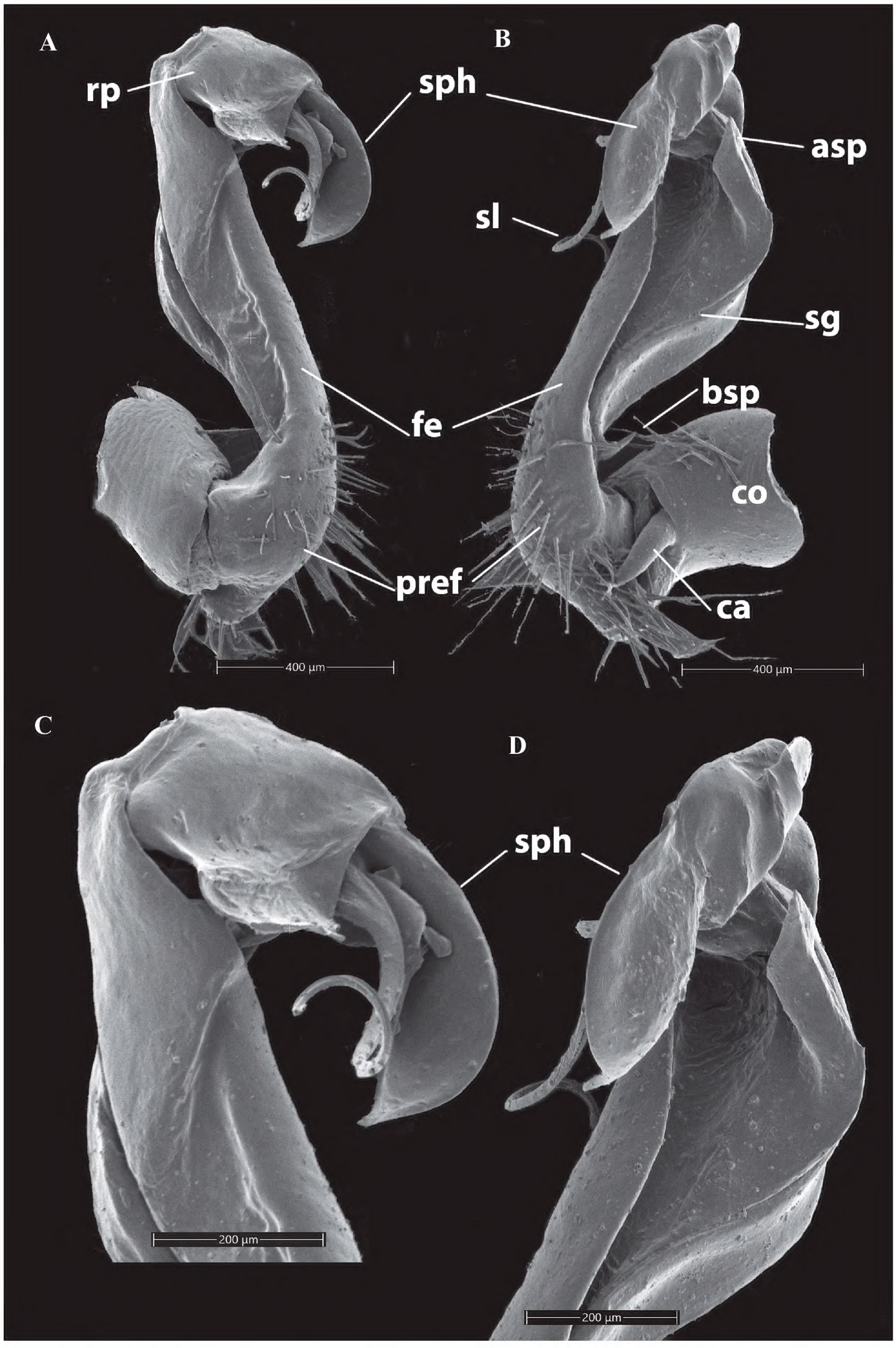

Figure 15. *Anoplodesmus gladius* sp. nov. Holotype (IEBR-Myr 903H). **A, B.** Left gonopod, lateral view (**A**), mesal view (**B**); **C, D.** Distal part of left gonopod, lateral view (**C**), mesal view (**D**). Abbreviations: ca = cannula; co = coxite; pref = prefemorite; fe = femorite; sg = seminal groove; sph = solenophore; sl = solenomere; bsp = basal spine of femorite; asp = apical spine of femorite; rp = rectangular process of solenophore.

Collum (Fig. 11A, B): a little wider than head, surface smooth, with two rows of setae: 4+4 close to anterior margin and 2+2 nearly posterior margin. All setae broken.

Body (Figs 11–12) submoniliform, width of ring 4<3<2=5, parallel-sided on rings 5–16, thereafter gradually tapering towards telson. Metatergal surface smooth,

shagreened, shining, with only one row of 2+2 setae near anterior margin. Transverse sulcus very poorly developed, superficial, possibly visible only on metaterga 5–18. Prozona and pleura also shagreened and shining. Stricture dividing pro- and metazona rather distinct and smooth, neither striolate nor beaded.

Paraterga (Figs 11A, B, 11D, 12A, 12C) strongly reduced, almost missing, slightly more easily traceable as lateral keels on pore-bearing segments than on poreless ones. Ozopore (Fig. 11B, 11D) formula normal, pores located on paraterga 5, 7, 9, 10, 12, 13, and 15–19. Pleurosternal carinae well-developed until segment 16, missing on subsequent ones.

Telson (Figs 12C–D, 13A): Epiproct long and curved down, with four small spinnerets at tip. Paraprocts semi-circular, each with two setae located on disk. Hypoproct roundly trapeziform, with two distolateral setiferous knobs (Fig. 13A).

Sternites (Figs 12B, 13B) sparsely setose, cross-impression with both transverse and longitudinal sulci moderately developed. Sternal cones obvious, front pairs slightly stouter, caudal pairs somewhat slenderer and longer. Sternite 5 with an elevated bifid lamina between coxae 4 and a ventrad-elevated setiferous process between coxae 5 (Fig. 13B).

Legs**:** slender and about 1.6 times as long as body height. Tarsal brushes present until ring 15, thereafter missing. Prefemora not swollen dorsally. Femora without modifications.

Gonopod (Figs 14–15) rather complex. Coxite (co) stout, about half length of telopodite, distoventral part sparsely setose. Prefemoral part as usual densely setose. Femorite (fe) stout, enlarged distad, swollen dorsally, with a basal spine and an acute spine (as) distomesally; separated from postfemoral region laterally by a distinct demarcation sulcus. Solenophore complex, curved posteriad, large blade-shaped with an acute terminal; basal part with a rectangular process (rp). Seminal groove running distodorsad fully on mesal side of femorite, Solenomere (**sl**) flagelliform, longer than solenophore, only its proximal half sheathed by solenophore.

Remarks. The gonopod solenomere is still long in comparison with length of the solenophore. Thus, the species is better to be assigned to the *A. elongissimus* group. It clearly differs from its other congeners in having a blade-shaped gonopod solenophore.

Habitats. The species was found under the leaf litter in moist environments. It moves quickly when disturbed.

Key to *Anoplodesmus* species known from Vietnam (based on male characters)

1	Gonopod without distofemoral spine	2
–	Gonopod with an obvious distofemoral process	5
2	Solenophore with only a process	3
–	Solenophore with two or more than two processes	4
3	Solenophore with a highly elaborated mirabilis-shaped process	*A. mirabilis*
–	Solenophore with a long, coiled, lobuliform process	*A. bilobus* sp. nov.
4	Solenophore with at least seven differently shaped spines	*A. nguyeni*
–	Solenophore with only two distinct distal processes	*A. borealis*
5	Gonopod femorite with a basal spine. Solenophore with 1–2 processes	6
–	Gonopod femorite without a basal spine. Solenophore with more than two processes	7
6	Solenophore blade-shaped, with a rectangular basal process	*A. gladius* sp. nov.
–	Solenophore complex, with two basal spines and a spiniform process in middle; tip strongly bifid	*A. lobus* sp. nov.
7	Solenophore with three dentiform processes distally and another two lobes parabasally on lamina medialis	*A. anichkini*
–	Solenophore with two long spines and a knife-shaped lobe distally. Lamina medialis with two spines parabasally, while lamina lateralis with two smaller spines	*A. solenophorus*

Phylogenetic analysis

The final aligned dataset of the gene 16S rRNA consists of 500 bp, including gaps from 31 samples of four sulciferinine genera (*Anoplodesmus*, *Kronopolites*, *Oxidus*, and *Tylopus*) and a root, *Antheromorpha* (Table 1).

The phylogenetic analysis showed the separations of *Anoplodesmus* species. Seven clusters or branches represent seven *Anoplodesmus* species, including *A. mirabilis*, *A. solenophorus*, *A. nguyeni*, *A. bilobus* sp. nov., *A. lobus* sp. nov., *A. gladius* sp. nov., and *Anoplodesmus* sp. (Fig. 16). All the species separations are well supported with high bootstrap values (more than 90%), except the relationship between *Anoplodesmus* sp. and *A. gladius* has a low bootstrap value (67%).

Four genera, *Anoplodesmus*, *Oxidus*, *Kronopolites*, and *Sellanucheza*, each forming their own branch, are separated from others with high bootstrap values (>79%), but not *Tylopus*. In other words, they are all monophyletic. The genus *Anoplodesmus* is closely related to the two genera *Tylopus* and *Oxidus*, with a bootstrap value of 89%. The 16S rRNA is known to be a slowly evolving gene, but only a short fragment of this gene was employed in this study. Therefore, incorporating more slowly-evolving genes, such as nuclear genes (18S rRNA or 28S rRNA) and a fast-evolving gene, e.g., cytochrome

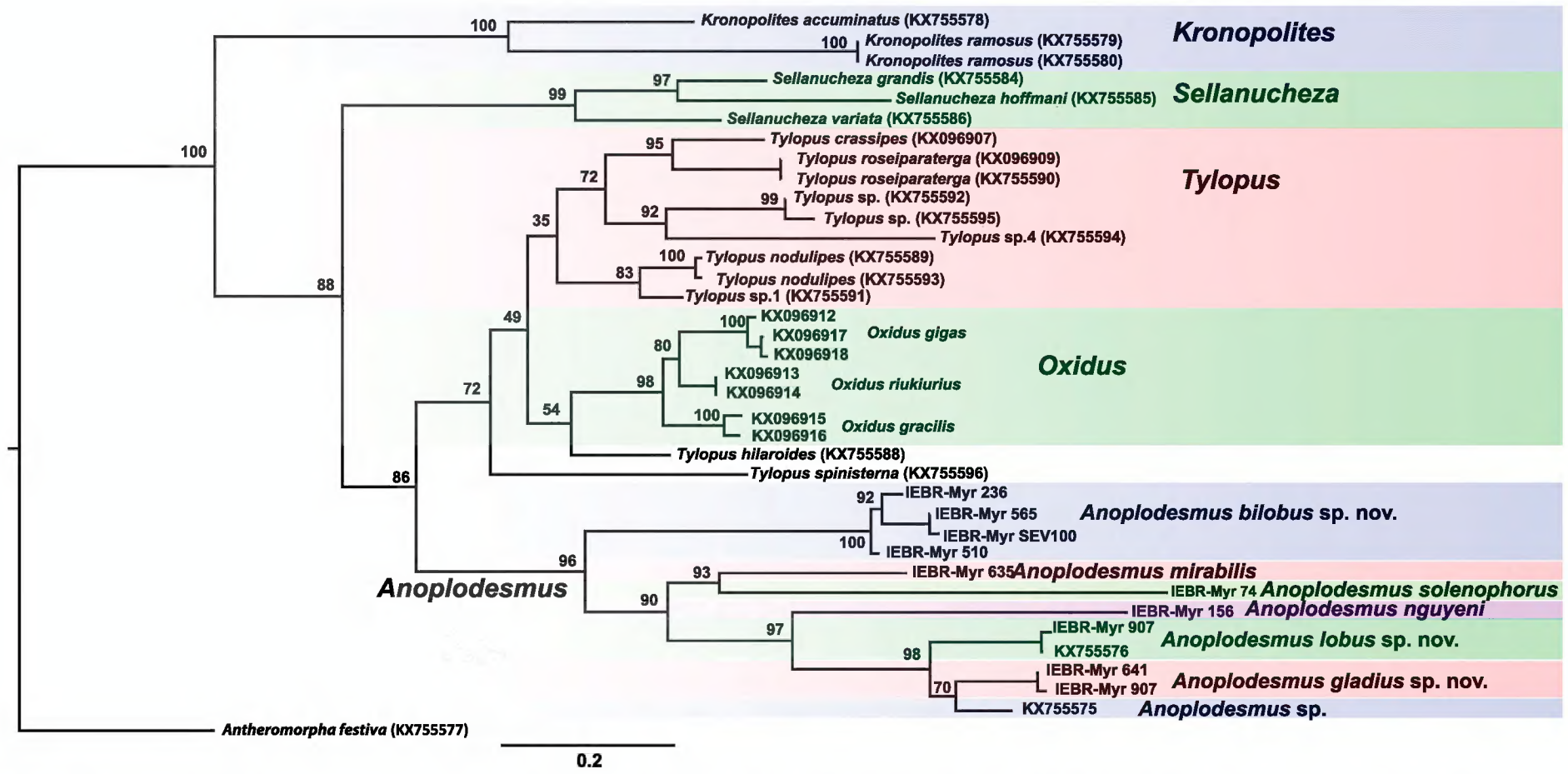

Figure 16. Phylogenetic relationship between sulciferinine species in Vietnam inferred from a 500 bp fragment of the 16S rRNA gene using the maximum likelihood analysis.

c oxidase subunit I (COI), could enhance phylogenetic resolution when assessing intergeneric relationships.

In addition, the genus *Tylopus* is shown to be a paraphyletic group. The species *T. hilaroides* is in the same clade as *Oxidus* species, whereas other *Tylopus* species form a sister clade with a supported bootstrap of 79%. The result is similar to that reported by Nguyen (2017). Given that *Tylopus* is a large genus with more than 70 species distributed in Vietnam, Thailand, Laos, Myanmar, and southern China (Likhitrakarn et al. 2016), only a few species were used in this study. The data is, therefore, likely to be very limited, and more species from other countries are needed to confirm the results.

Conclusion

The number of species of the genus *Anoplodesmus* has increased to eight, with discoveries of three new species, *Anoplodesmus lobus* sp. nov., *A. bilobus* sp. nov., and *A. gladius* sp. nov. More intensive surveys may reveal more new species in Vietnam, a country with rich biodiversity.

Acknowledgments

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